

**ROOT CAUSE ANALYSIS OF RULE VIOLATIONS BY AVIATION
MAINTENANCE TECHNICIANS**

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ROOT CAUSE ANALYSIS OF RULE VIOLATIONS BY AVIATION MAINTENANCE TECHNICIANS¹

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SUMMARY

This research project was implemented as part of a larger effort to help Human Factors (HF) practitioners, and others in the aviation maintenance community, understand, evaluate, and minimize maintenance errors. The specific goal of this project was to study the root causes of rule violations by aviation maintenance technicians so that appropriate guidance materials could be developed and, maintenance errors and thereby, rule violations could be minimized.

The objective during the first year (November 2000 – November, 2001) of this project was to develop a preliminary database of cases and determine the root causes of the errors identified therein. These errors were to be classified as attributable to either organizational or individual factors.

Three groups of data were analyzed. First, FAA's records regarding rule violation cases that were closed between January 1998 and December 2000 (n=1555) were analyzed to establish the severity of the rule violation problem and to determine the most common violations and their associated sanctions. Second, self-reported errors documented by the Aviation Safety Reporting System (n=939) were analyzed to establish the general areas of vulnerability from organizational and individual perspectives. Third, actual rule violation investigation reports (n=30) provided by our industry partners were analyzed to determine the root causes of these violations. The root causes were, again, classified in terms of organizational and individual factors.

In conclusion, this report presents a reliable matrix of organizational and individual factors that need to be addressed in order to minimize rule violations due to maintenance errors. In the future, guidance materials will have to be developed to help our industry partners minimize their rule violation cases. The effects of guidance materials will have to be tracked and measured with respect to changes in the number of rule violation cases, the amount of fines, and the severity of incidents. Once field-tested, these guidance materials could be published as an Advisory Circular.

¹ The research reported here, as well as this report, benefited greatly from the help of Professor J.C. Taylor (Santa Clara University) and four research assistants : Mr. Baru Harsa, Ms. Prachi Sharma, Mr. Oscar Becerra, and Mr. A. Troy Freymiller. Excellent guidance and encouragement by the project sponsor's technical officer, Ms. Jean Watson, was always available and freely given. Additionally, San Jose State University Foundation provided matching support for labor costs. Among our industry partners, we are extremely grateful to one airline and one mechanic labor union for providing the case studies, and we also appreciate the help of FAA-AFS 600 in providing the rule violation data in a timely manner.

BACKGROUND

The FAA enforcement action data for 1999 (the year before this project was approved) showed that 79 certificate actions had resulted in approximately \$2.25M in fines due to rule violations by aircraft mechanics (FAA, 1999). This equates to about \$28,000 per mechanic in one year. This cost does not account for the expenses incurred by the FAA, the industry, and the labor unions in investigating and litigating the cases. Such certificate actions are usually initiated by a letter of investigation (LOI) issued to the aviation maintenance technician (AMT) who was responsible for the maintenance action that potentially impacts the airworthiness or safety of the aircraft being maintained. From that point forward, substantial resources from the FAA and the industry are spent in these investigations. Considering the high volume of LOIs, the FAA, AMTs, and union organizations were very interested in working with the researchers so that the researchers could collect and analyze case data and ultimately recommend solutions without compromising the identity of the actual individuals/operators involved in these cases. This research symbolized an unprecedented level of trust among AMTs, union member, the FAA, and the academia to develop mutually beneficial set of guidelines that minimize the number of LOIs and the subsequent certificate actions.

Root Cause Analysis

Three root cause analysis tools were reviewed for this project: Aviation Safety Human Reliability Analysis Method (ASHRAM), Maintenance Error Decision Aid (MEDA), and Causation Trainer (CT).

ASHRAM was developed by Miller and Forester (2000) of Sandia National Laboratories to conduct detailed analysis from either retrospective or prospective approaches. The retrospective approach enables users to map the error forcing conditions, including human, technical, procedural, and environmental aspects that may have contributed to the error. Such an analysis therefore provides a very detailed and comprehensive model of error causation, enabling the users to implement the optimum intervention. The prospective approach allows users to test plausible scenarios of events that have not yet occurred. Such an approach allows the users to consider the entire system and evaluate its weaknesses from an error causation perspective.

MEDA was developed by Rankin and Allen (1996) of the Boeing Company to help maintenance professionals identify errors, their effects, and their contributory factors. This tool was designed to be a field investigation tool, and as such it is used as a form that is filled-out by a MEDA investigator. At a later time, it could be encoded in a computerized database for trend analysis.

CT was developed by David Marx (1999) to train field investigators to determine causal relationships between certain conditions, actions, and their effects. The CT system classifies the causes into human error, mechanical failure, or a rule violation (not necessarily regulatory violations).

In this project, the CT system was used to determine the causal relationship between conditions/actions that led to the specific event such as a regulatory violation or a fatal accident. These causal conditions were then classified in terms of organizational or individual factors. The terminology for organizational/individual factors was based on a composite causal matrix developed by the researchers during this project. ASHRAM was not used because none of the data sources provided sufficient details.

I. Nationwide Rule Violation Cases Against Part 121 and 145 Mechanics

Data Collected

Under the Freedom of Information Act (FOIA), 5 U.S.C § 552, all FAA regional offices were requested to send records from Enforcement Information System pertaining to actions taken against certificated airframe mechanics, certificated powerplant mechanics, and certificated airframe and powerplant mechanics. These regional requests were consolidated by AFS-600, Oklahoma City, and data consisting of 1,555 records were forwarded to the researchers. These records consist of all rule violation cases against certificated aircraft mechanics who were working for either a 14CFR Part 121 or Part 145 certificate holder. The overall distribution of the violations was as follows: 529 cases for 1998, 480 cases for 1999, and 546 cases for 2000. Although Table 1 shows that over 90 percent of the violation cases were at Part 121 operator facilities, it does not mean that mechanics at Part 145 operators make fewer errors. Since the majority of the mechanics at Part 145 operators tend to be non-certificated and since Part 145 operators tend to perform only about 8-10 percent of the heavy maintenance work, the number of rule violation cases against mechanics at Part 145 operators seem to be significantly lower. Note: each case may or may not consist of multiple regulatory violations.

Table 1: Distribution of rule violation cases across Part 121 and Part 145 operators

Operator Type	1998	Percentage	1999	Percentage	2000	Percentage
Part 121	490	93	436	91	519	95
Part 145	37	7	41	8	26	5
Missing Data	2		3	1	1	
Total	529	100	480	100	546	100

Comparison of Rule Violation Data Across FAA Regions

A comparison of the rule violation cases across the nine FAA regions indicates that certain regions such as the Southwest and Southern tend to have the majority of the rule violation cases. Figure 1 illustrates the distribution of violations by FAA regions.

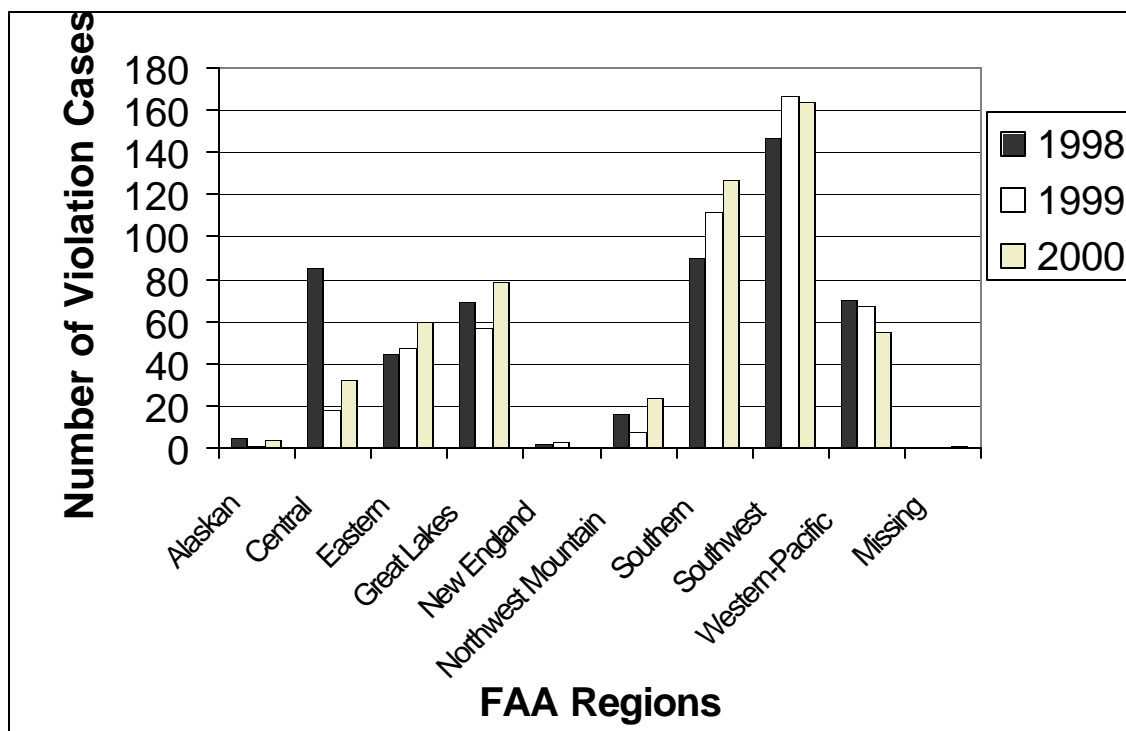


Figure 1: Distribution of rule violation cases by FAA regions

14 CFR Part 121 Data: Air Carrier Employees

Regulations Cited

For every rule violation case, at least one specific federal regulation that was violated by the certificate holder is cited by the FAA investigator. Depending on the nature of the case, the particular violation may be under the individual person's span of control (for example Part 43 specifies the acceptable methods and practices that are expected to be followed by every certificated mechanic—at the individual level) or it may be the organization's responsibility (for example, Part 121 specifies the training requirements that must be met by all 121 operators: if the operator does not provide adequate training, that operator may be in violation—at the organizational level).

The following sections present regulatory violations at individual and organizational levels. When multiple regulations were cited, it was reflected in the increase in the frequency of citations, but not in the total number of cases. It is clear from these data that the citations at the individual level are much more common than those at the organizational level. Also, 14CFR Part 43.13 represents the bulk of the citations (35-63 percent of the cases).

Individual Violations: Table 2 presents the distribution of top five citations, at the individual level, in 490 cases of the year 1998. The percentage distribution was calculated based on the total of 490 cases.

Table 2: 1998 Citations at individual level among Part 121 employees

Regulation	Frequency	Percent Cases
43.13A	203	41.4
43.13B	98	20
43.13C	14	2.9
43.9A	21	4.3
43.16	15	3.1

Table 3 presents the distribution of top five citations, at the individual level, in 436 cases of the year 1999. The percentage distribution was calculated based on the total of 436 cases.

Table 3: 1999 Citations at individual level among Part 121 employees

Regulation	Frequency	Percent Cases
43.13A	180	41.3
43.13B	73	16.7
43.13C	19	4.4
43.9A	13	3
43.16	11	2.5

Table 4 presents the distribution of top five citations, at the individual level, in 519 cases of the year 2000. The percentage distribution was calculated based on the total of 519 cases.

Table 4: 2000 Citations at individual level among Part 121 employees

Regulation	Frequency	Percent Cases
43.13A	155	29.9
43.13B	78	15
43.13C	25	4.8
43.9	10	1.9
43.16	29	5.6

Organizational Violations: The following tables illustrate citations at the organizational level. In comparison with the individual level citations, the organizational citations are marginal.

Table 5 presents the distribution of top four citations, at the organizational level, in 490 cases of the year 1998. The percentage distribution was calculated based on the total of 490 cases.

Table 5: 1998 Citations at organizational level among Part 121 employees

Regulation	Frequency	Percent Cases
121.369B	9	1.8
121.701A	3	0.6
121.363	3	0.6
121.709	4	0.8

Table 6 presents the distribution of top five citations, at the organizational level, in 436 cases of the year 1999. The percentage distribution was calculated based on the total of 436 cases.

Table 6: 1999 Citations at organizational level among Part 121 employees

Regulation	Frequency	Percent Cases
121.369B	20	4.6
121.701A	4	0.9
121.363	3	0.7
121.628A5	2	0.5
121.709	6	1.4

Table 7 presents the distribution of top four citations, at the organizational level, in 519 cases of the year 2000. The percentage distribution was calculated based on the total of 519 cases.

Table 7: 2000 Citations at organizational level among Part 121 employees

Regulation	Frequency	Percent Cases
121.369B	7	1.3
121.709	8	1.5
121.628A5	1	0.2
121.701A	5	1

14 CFR Part 145 Data: Approved Repair Station Employees

Regulations Cited

Once again, the regulations were classified as individual level if the work was within the individual person's span of control and organizational if the work was within the organization's span of control. Considering that the number of rule violation cases in Part 145 repair stations were quite low compared to those in Part 121 air carriers, the citations at the organizational level were practically non-existent.

Table 8 presents the distribution of top four citations, at the individual level, in 37 cases of the year 1998. The percentage distribution was calculated based on the total of 37 cases.

Table 8: 1998 Citations at individual level among Part 145 employees

Regulation	Frequency	Percent Cases
43.13a	23	62.2
43.13b	13	35.1
43.12a	1	2.7
43.5	2	5.4
43.9	6	16.2

Table 9 presents the distribution of top four citations, at the individual level, in 41 cases of the year 1999. The percentage distribution was calculated based on the total of 41 cases.

Table 9: 1999 Citations at individual level among Part 145 employees

Regulation	Frequency	Percent Cases
43.13a	12	29.3
43.13b	2	4.9
43.5	3	7.3
43.12a	1	2.4
43.9a	1	2.4

Table 10 presents the distribution of top four citations, at the individual level, in 26 cases of the year 2000. The percentage distribution was calculated based on the total of 26 cases.

Table 10: 2000 Citations at individual level among Part 145 employees

Regulation	Frequency	Percent Cases
43.13a	9	34.6
43.13b	7	26.9
43.16	4	15.4
43.12a1	1	3.8
43.9a	1	3.8

Discussion

The Federal Aviation Regulations Parts 43.13A, B, and C address the issue of general performance rules that all certificated mechanics are expected to follow. Specifically, they require that the mechanics use approved maintenance manuals, tools, and test equipment such that the maintenance work is performed in accordance with the acceptable industry standards. Part 43.16 addresses the issue of airworthiness limitations. Specifically, it is addressed at inspectors or mechanics who perform airworthiness inspections in accordance with an approved inspection program under Parts 121, 123, 127, or 135. At the organizational level, the company is most likely to be cited for not meeting the maintenance manual requirements specified in Part 121.369B, including the maintenance procedures, documentation, personnel accountability, and inspection procedures. For individuals working under Part 145 operator's certificate, another notable citation is Part 43.12 which concerns falsification, reproduction, or alteration of maintenance records. These data do not indicate that falsification of maintenance records is a significant problem in the industry.

II. Aviation Safety Reporting System Data

Description of Data

Under the Aviation Safety Reporting System (ASRS), established in 1975, pilots, mechanics, flight attendants, etc. are encouraged to report unsafe conditions or acts so that the Federal Aviation Administration (FAA) can take appropriate corrective action. The ASRS contractor de-identifies the reports such that individuals or organizations associated with the specific unsafe situation cannot be identified. Since 1975, ASRS has received a total of over 150,000 reports. However, the first ASRS-maintenance report was recorded in January 1996. Since that time, the use of ASRS reporting forms by the maintenance community has been increasing. By the end of 2000, ASRS had 939 maintenance reports on record (ASRS, 2001). These self-reports illustrate some of the trends in maintenance practices and therefore they serve as indicators of the overall safety climate. Some issues that arise from their analysis concern organizational structure and processes that lead to maintenance errors, while other issues concern individual practices that lack professionalism.

Delimitations and Limitations

This analysis was delimited by the following facts: (a) all the ASRS reports were voluntary submissions, (b) the level of detail in these reports was inconsistent, and (c) only 20 percent of the incoming reports are documented and reported by ASRS. Since these reports are submitted voluntarily and they do not represent the entire population of a particular company or maintenance facility, the report is subject to the reporter's personal bias. Considering these delimitations, the ASRS data are not accurate enough to design interventions or to measure the effects of a certain intervention; however, these reports are plausible means to corroborate the limited hard evidence such as accident/incident reports and FAA enforcement statistics.

This analysis was limited by the fact that data were coded by a single individual; therefore, the researcher's personal bias in coding a particular case as either due to an individual factor or an organizational factor cannot be ruled out.

Organizational Versus Individual Factors

Organizational-type factors are systemic; whereas, individual-type factors are specific to the particular person performing the maintenance action. Neil Johnston used a "substitution test" (cited in Reason, 1997) to determine whether an error was primarily system-induced or whether it was primarily attributable to the individual. According to this test, if the given error was equally likely to be committed by another individual under similar conditions, the error was systemic—hence classified in this study as due to an organizational-type factor; otherwise, it was limited to the individual—hence classified in this study as due to an individual-type factor.

The following three failure-factor taxonomies were reviewed to determine the various organizational and individual factors: (a) Reason's (1997) eleven General Failure Types (GFTs), (b) Boeing's (Rankin and Allen, 1996) ten contributing factors per the MEDA form, and (c) Transport Canada's Dirty Dozen items (*c.f.* Taylor and Christensen, 1998). When these three

taxonomies (Tables 11, 12, 13, 14, and 15) were cross-mapped to develop a list of primary causal factors, thirteen clusters of organizational-type factors were produced (see Table 16) and twelve clusters of individual-type factors were produced (see Table 17).

Table 11: Reason's General Failure Types (GFTs)

Number	General Failure Type
1	Hardware
2	Design
3	Maintenance Management
4	Procedures
5	Error-enforcing conditions
6	Housekeeping
7	Incompatible goals
8	Communication
9	Organization
10	Training
11	Defenses

Table 12: Factors according to MEDA

Number	Error Factors
1	Information
2	Equipment/Tools
3	Aircraft Design/Configuration/Parts
4	Job/Task
5	Technical Knowledge/Skills
6	Individual Factors
7	Environment/Facilities
8	Organizational Factors
9	Leadership/Supervision
10	Communication

Table 13: Sub-factors under MEDA's individual factors

Number	Sub-factors under Individual Factors
1	Physical Health
2	Fatigue
3	Time Constraints
4	Peer Pressure
5	Complacency
6	Body Size/Strength
7	Personal Event
8	Workplace Distractions
9	Other

Table 14: Sub-factors under MEDA's organizational factors

Number	Sub-factors under Organizational Factors
1	Quality of Support from Other Depts.
2	Company Policies
3	Not Enough Staff
4	Corporate Change/Restructuring
5	Union Action
6	Work Process/ Procedure
7	Work Process/ Procedure Not Followed
8	Work Process/ Procedure Not Documented
9	Work Group Standard Practice/Norm

Table 15: The Dirty Dozen

Number	Dirty Dozen Item
1	Lack of Awareness
2	Lack of Knowledge
3	Complacency
4	Lack of Communication
5	Lack of Teamwork
6	Lack of Assertiveness
7	Stress
8	Fatigue
9	Pressure
10	Lack of Resources
11	Distractions
12	Norms

Table 16: Cross-mapped organizational factors, as used in this analysis

Number	Organizational Factors
1	Hardware/Equipment/Tools/ Lack of Resources/Not Enough Staff
2	Design/ Configuration/ Parts
3	Maintenance Management/Leadership/ Supervision/ Company Policy
4	Work Processes/Procedures/ Information
5	Error-enforcing conditions/Norms/Peer Pressure
6	Housekeeping
7	Incompatible goals
8	Communication Processes
9	Organizational Structures/Corporate Change/Union Action
10	Training/ Technical Knowledge/ Skills
11	Defenses
12	Environment/Facilities
13	Lack of Teamwork

Table 17: Cross-mapped individual factors, as used in this analysis

Number	Individual Factors
1	Physical Health
2	Fatigue
3	Time Constraints
4	Pressure from Management
5	Complacency
6	Body Size/Strength
7	Personal Event/Stress
8	Workplace Distractions
9	Lack of Awareness
10	Lack of Knowledge
11	Lack of Communication Skills
12	Lack of Assertiveness

The cross-mapping of factors, as presented in Tables 16 and 17, was based on the definitions of these factors according to Reason, Boeing, and Transport Canada. Lack of Communication and Lack of Knowledge seem to fit under both organizational as well as individual classifications. For example, Lack of Communication was considered as an organizational factor when organizational structures and process — shift turnover rules, documentation change protocol, or lack of inter-departmental communications — inhibit safe maintenance practices. The same factor was considered as an individual-type factor when personal skills/personality characteristics prevented that individual from asking for help or from being thorough in his/her documentation of the work performed.

Lack of Knowledge was considered as an organizational factor when the organization failed to provide adequate training, but it was considered to be an individual-type factor when in spite of adequate training, the individual had not mastered the skills through experience in doing the job.

Error Management Strategies

Error management strategies exist at both organizational as well as individual levels. At the organizational levels, they typically appear in the form of procedures, inspection/approval protocol, or training. At the individual level, the error management strategies tend to be in the form of personal habits such as double-checking the work prior to release, using memory aids that help track the status of a job when interrupted, or seeking a colleague's advice.

Another way of classifying these error management strategies is based on whether they are reactive or proactive. Reactive strategies, typically involving incident investigations using MEDA-like processes, seek to identify causal factors responsible for the mishap and develop comprehensive solutions to minimize the recurrence of similar mishaps in the future. The proactive error management strategies are typically aimed at recognizing the error inducing situations and preventing the error in real time.

Table 18: Hobbs' correlations between error-producing factors and unsafe acts

Error Factor	Unsafe Acts
Environment	Slip
Fatigue	
Equipment	
Pressure	Lapse
	Violation*
	Failure to Perceive
Training	Knowledge-based error
Procedures	Rule-based error
Coordination	
Previous Error	

* Hobbs used Reason's definition (Reason, 1997 p 51) of the term *violation*.

Hobbs (2001) discovered a link between maintenance errors and error-producing conditions. His results indicate a correlation between the types of error producing conditions and the types of maintenance errors. Table 18 presents these correlations. Such research could be used to make reactive error management strategies more effective because, as indicated in Table 8, slip-type errors can be reduced by either improving the work environment, reducing worker fatigue, improving the ground support equipment, or all three.

The same data, Table 18, could also be used in proactive error management strategies. For example, if training effectiveness deteriorates, knowledge-based errors are likely to increase. Therefore, if training time must be reduced, then some other means of error management such as pairing-up of experienced and inexperienced mechanics or providing computer-assisted diagnostic tools will have to be introduced.

In general, the current literature on organizational factors, individual factors, and error management techniques indicates that there are both organizational as well as individual factors that lead to maintenance errors and certain error-producing conditions tend to produce certain types of maintenance errors.

This analysis used ASRS data to determine primary and secondary causal factors and classified them as either organizational (system-induced) or individual (single person induced).

Method

Primary versus Secondary Causal Factors

ASRS maintenance reports typically describe the maintenance error, the effect of that error, and the causal factors leading to the error. Primary causal factors were the ones that were specifically stated as the ones directly responsible for the maintenance error. Secondary causal factors were the ones mentioned as the ones directly responsible for the primary causal factor and indirectly responsible for the maintenance error. Out of the 939 ASRS reports that were analyzed, 918 reports were found to identify the primary causal factor and 254 reports were found to identify secondary causal factors. Twenty-one reports did not have enough information to determine primary causal factors.

The 918 ASRS maintenance reports were classified into two groups based on Neil Johnston's substitution test, as described earlier. Group A (n = 459) comprised of reports wherein the primary causal factors were attributable to an organization-type factor and Group B (n = 459) comprised of reports wherein the errors were primarily attributable to an individual-type factor. The equal distribution of reports is purely coincidental.

All 918 reports were further analyzed to test for the presence of secondary causal factors. These factors were the underlying causes for primary causal factors. The 254 reports that identified secondary causal factors were coded using the combined list of factors from Tables 16 and 17.

Results

The top five overall effects of maintenance errors in ASRS-reported cases were unairworthy dispatch, none, rework, air turnback, and aircraft damage (see Figure 2). Figure 3 reports that the top four maintenance errors were improper installation, improper documentation, improper fault isolation, and sign-off of work not performed.

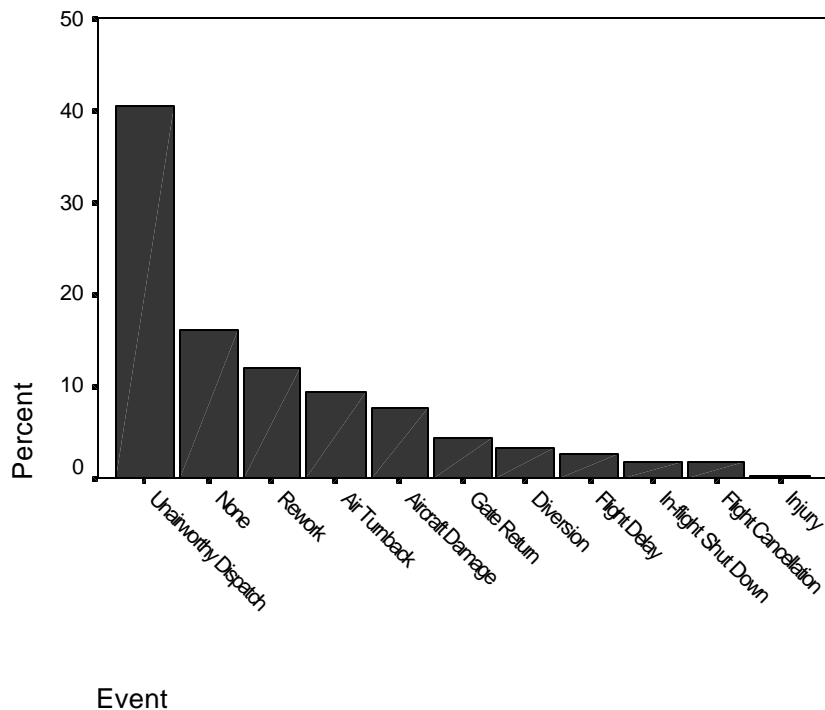


Figure 2: Overall effects of maintenance errors in ASRS-reported cases

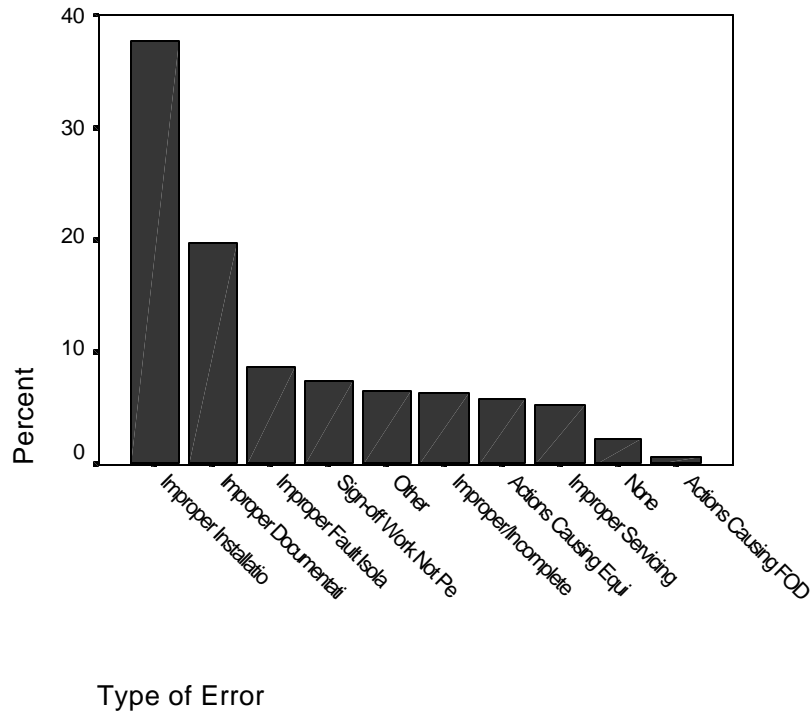


Figure 3: Maintenance error types in ASRS-reported cases

Group A data were coded for organizational factor types using the taxonomy presented in table 6, and Group B data were coded for individual factor types using the taxonomy presented in Table 17. The combined Group A and Group B data were further analyzed using the combined taxonomies of Tables 16 and 17 to identify the secondary causal factors.

Through examination of primary and secondary causal factors, the top five clusters of primary-organizational factors, primary-individual factors, and secondary causal factors were identified.

From the total sample of 939 maintenance error cases, 459 errors were primarily attributable to organizational-type factors and 459 errors were primarily attributable to individual-type factors.

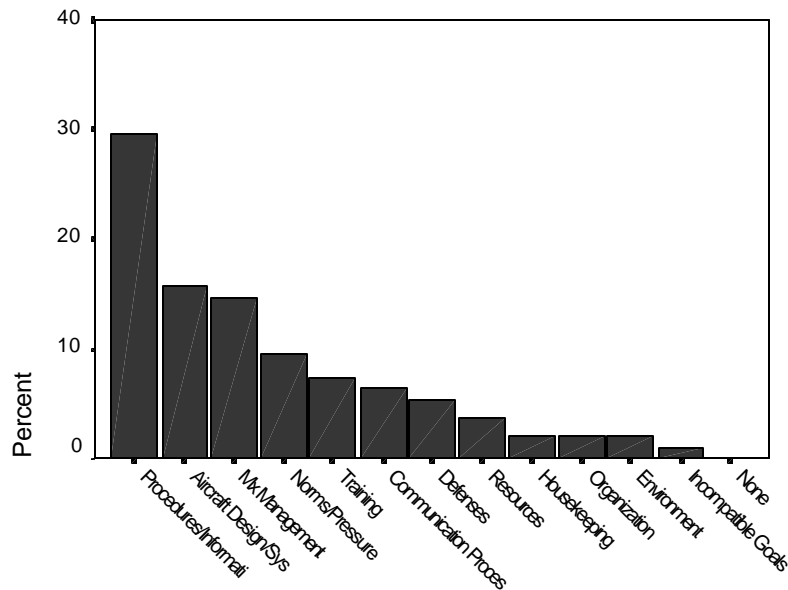


Figure 4: Primary organizational factors

The top five organizational factors identified in the ASRS data (see Figure 4 above) are (1) procedures or information quality, (2) aircraft design/configuration of system or quality of parts, (3) maintenance management or leadership, (4) workplace norms/peer pressure, and (5) lack of training.

The top five individual factors identified in the ASRS data set (see Figure 5 below) are (1) lack of awareness, (2) complacency, followed by (3) time constraints, (4) lack of knowledge or experience, and (5) workplace distractions.

The top five secondary causal factors ($n = 254$) are presented in Figure 6. These factors are (1) procedures or information quality, (2) time constraints, (3) lack or failure of defenses, (4) lack of training, and (5) complacency.

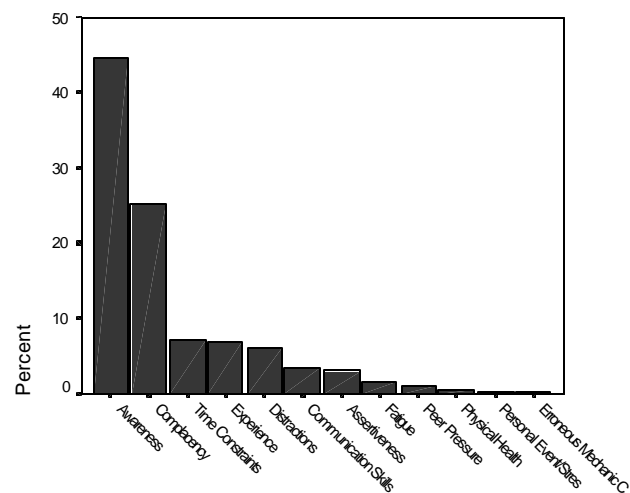


Figure 5: Primary individual factors

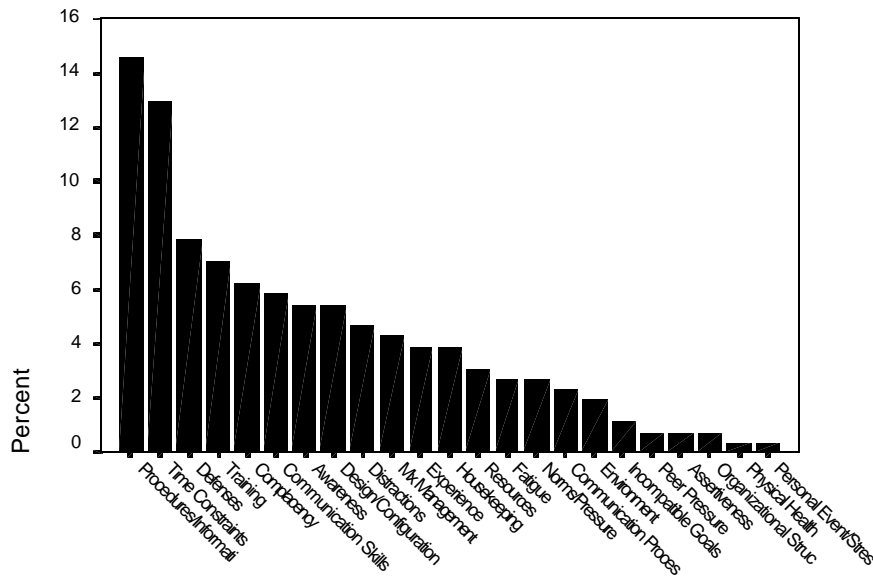


Figure 6: Secondary causal factors

Discussion

These ASRS data indicates that organizations need to provide (1) improvements in procedures/information, (2) management that encourages safer maintenance practices through improvements in training, planning, and task supervision, and (3) interaction among the manufacturers and the maintainers such that the designs of aircraft, systems, and components are “Murphy-proof.” At the individual-level, the ASRS data indicate that the maintenance personnel need to (1) have a better situational awareness, (2) reduce complacency through better self-checking mechanisms and improved communication skills, (3) improve their technical knowledge through training and experience.

III. Case Studies

Data Collected

Rule violation cases are typically handled by either the Quality Assurance Department or the respective labor union. In our study, one airline and one labor union provided the data. These data were received after the investigation had been completed and the final action had been executed. Therefore, this research was archival rather than field study consisting of first-hand investigation and interviews. Thirty such cases were obtained over the first year of this project. Although additional cases were expected at the start of this project, the actual delivery of data was limited due to the following reasons: (a) belaboring contract negotiations between one of the key airline-union partners; (b) reluctance of the quality assurance department of one airline to share the data; and (c) loss of several key champions of maintenance safety as well as reallocation of resources from safety to security after the economic downturn following the terrorist attacks of September 11, 2001.

Method

The thirty rule violation cases were analyzed using the composite causal matrices presented earlier in Tables 16 and 17. Organizational as well as individual factors contributing to the final action that resulted in a federal regulation violation were identified. Additionally, all cases were organized in a causal diagram based on Marx's (1999) Causation Trainer system. The Causation Trainer system allowed the researchers to organize all rule violation cases in a consistent format to facilitate further understanding of the relationship between the contributing factors and the final outcome.

Results

Figure 7 illustrates the overall effects or events according to the MEDA classification, in rule violation cases. Per Figure 7, unairworthy dispatch continues to be the top consequence of maintenance errors; however, there were at least 20 percent of the cases where there was no negative outcome on the safety or airworthiness of the aircraft. In such instances, the error was discovered by someone prior to its natural manifestation in the form of a flight-affecting consequence.

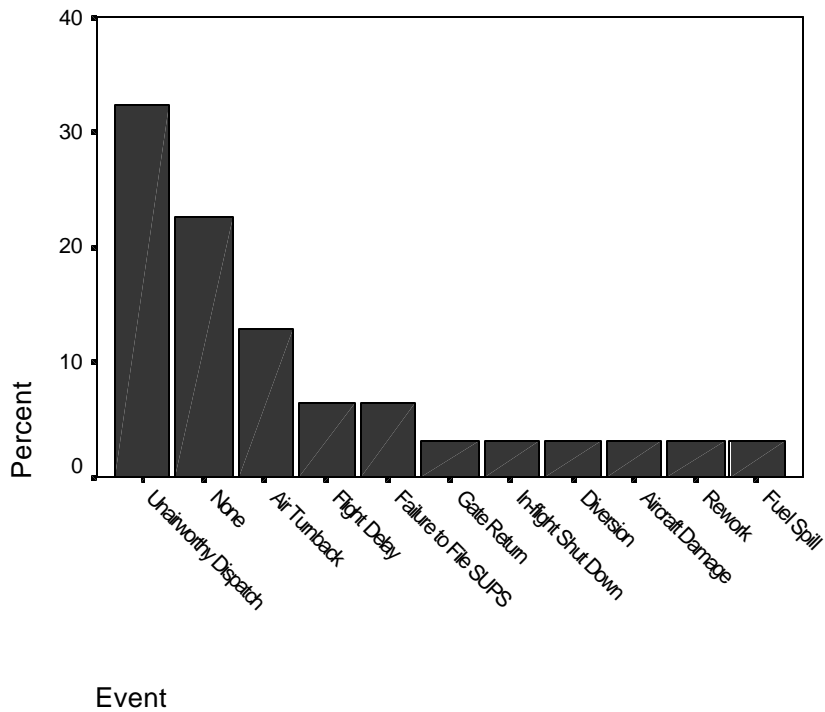


Figure 7: Overall effects of maintenance errors in rule violation cases

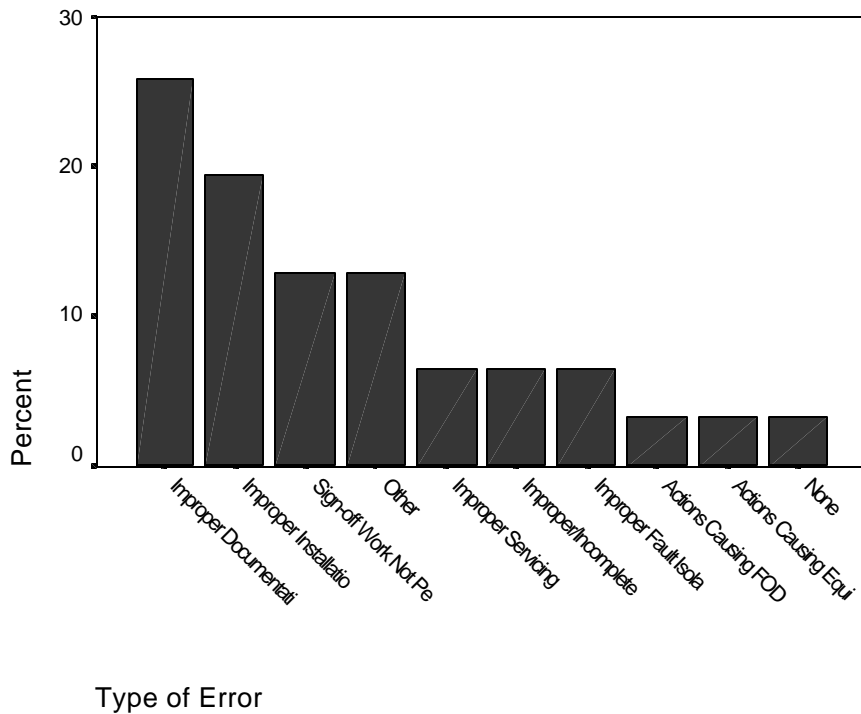


Figure 8: Maintenance error types in rule violation cases

Reviewing the types of errors, from Figure 6, responsible for the maintenance events, it is not surprising that improper documentation is the most frequent error. Documentation is a key aspect of ensuring airworthiness of an aircraft. Consequently, improper documentation is reported as a maintenance error in 50 percent of the cases resulting in unairworthy dispatch. Other errors worth noting are improper installation and sign-off of work not performed.

Individual Factors

When factors contributing to a maintenance error seemed to be within the individual mechanic's span of control (again as per the Neil Johnston substitution test presented earlier in this report), the contributing factors were classified as individual. Figure 7 illustrates that the top two individual factors are "Lack of Awareness" and "Complacency." Interestingly enough these factors represent the opposite sides of the knowledge/experience spectrum because people with low knowledge/experience are susceptible to lack of awareness of their task or surroundings; while, people with high knowledge/experience are susceptible to complacency in their tasks. The last category listed in this figure is due to an erroneous issuance of the mechanic certificate. The individual's practical experience was questionable and hence the FAA questioned the legitimacy of his certificate. Since this was an individual matter, a matter of possible falsification of records, it was classified as an individual factor.

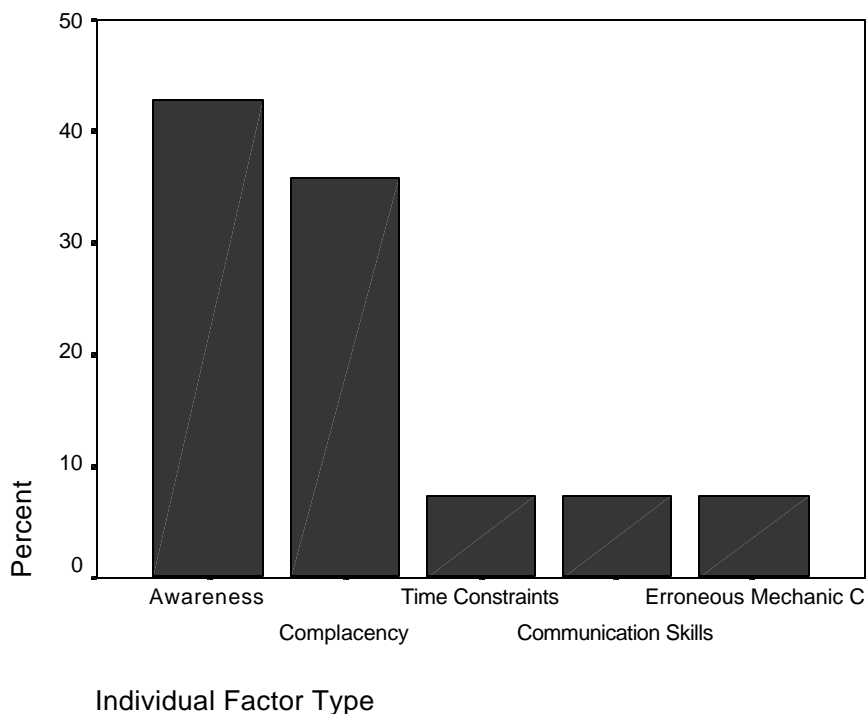


Figure 9: Individual factors in rule violation cases

Organizational Factors

By far the most significant organizational factor is “Maintenance Procedures/Instructions.” These procedural factors include inconsistencies in the dispatch criteria per the Minimum Equipment List, ambiguous technical procedures involving assembly/disassembly of parts, and vague instructions such as “return aircraft to normal.”

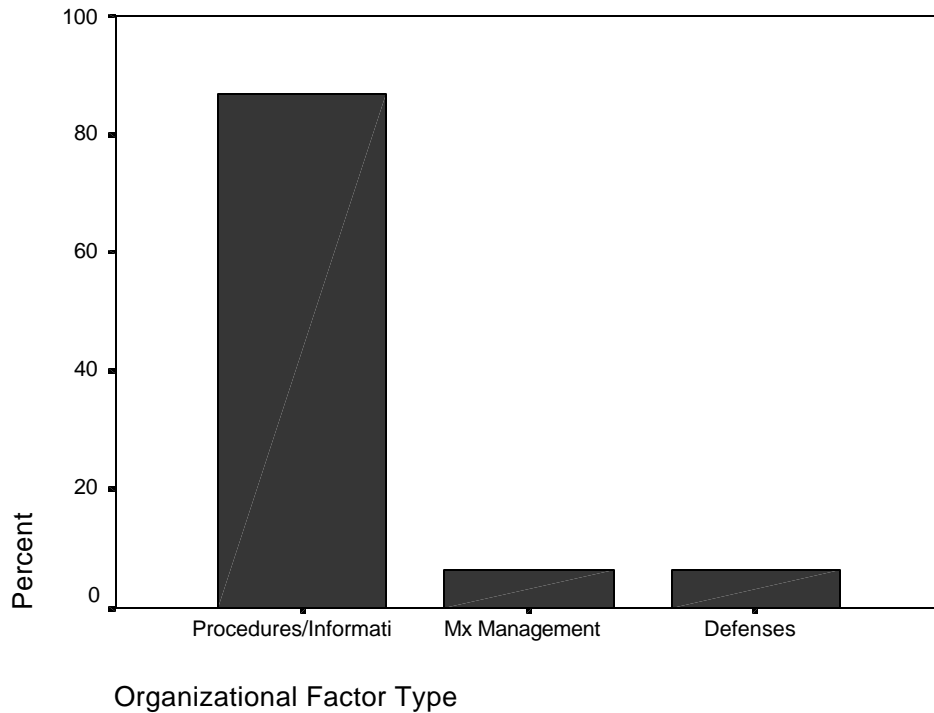


Figure 10: Organizational factors in rule violation cases

The maintenance management is reported as an organizational factor in Figure 10 because it represents cases wherein either the management did not ensure that the mechanic had received appropriate training in the task assigned to him or the management failed to ensure that the maintenance manuals/instructions were updated in a timely manner. Failure of defenses refers to times when multiple people failed to recognize a non-compliance of an airworthiness directive.

IV. Conclusions and Recommendations

State of Rule Violation Investigation and Analysis

Rule violation investigation is conducted by at least two parties: the FAA and either the company or the labor union who represents the certificate holder. The FAA investigation typically starts with an allegation that certain Federal Aviation Regulations may have been violated. The certificate holder is given an opportunity to respond to these allegations. Whether the certificate holder responds to the FAA or not, the investigation proceeds and final citation is issued based on the FAA inspector's investigation. In such citations, the causal analysis is not reported. Only the specific regulations that were violated are reported. The company or the labor union, on the other hand, tends to do a causal analysis because they are charged with implementing a comprehensive fix that will prevent such violations in the future. However, this project noted inconsistencies in the scope and format of such investigations. Such inconsistencies are attributable to lack of training in conducting investigations as well as the tremendous workload involved in researching, documenting, and analyzing the case. Typically, neither the company nor the labor unions have the resources to dedicate a person to perform such investigations.

Some companies have started using MEDA as their basic investigation and analysis tool. The results of such use were not available during the course of this project.

Correlation of Causal Factors

ASRS data, Rule Violation data and Accident data indicate that maintenance errors stem from issues at both organizational as well as individual levels. Specifically, the issue of maintenance procedures/instructions is consistently prominent in all three databases. A detailed look at the maintenance procedures/instructions revealed that the problem lies in what could be called "managing in the void" (Taylor & Felton, 1993 pp. 94-95). This term refers to people having to make decisions in situations that they have never encountered before. For instance, maintenance publications do not tend to pose a problem if they have specific instructions related to the task; however, there are times when no specific instructions are available. Under such circumstances, the mechanic is faced with a choice to either improvise or refuse to perform the job. When a job is not improvised correctly or an error is made during the improvisation process, a maintenance-related "event" is highly likely.

Recommendations

1. Standardize Data Collection: One significant problem in analyzing rule violation cases is that of lack of standardized data. Every investigation seemed different in terms of depth and breadth of the data collected during the investigation. At the time of this writing, no known reporting or data collection format has been adopted as the corporate or industry standard. Although MEDA and Causation Trainer are available, their use as rule violation or accident/incident investigation standard has not been universally accepted. In that sense, the researchers recommend standardized training to all incident/accident investigators so that the depth and the breadth of the data collected is consistent.

2. Organizational & Individual Risk Management: Risk must be understood and managed at both organizational as well as individual level. The ASRS and rule violation data indicate that organizations increase risk when their maintenance documentation is not current/correct/consistent. Similarly, individuals increase risk when they are either not fully aware of the complications of their task or they are complacent about their task.
3. Management in the Void: Individuals need to be taught the skills necessary to make decisions, either jointly with others or independently, that are conservative and replicable in the absence of published procedures. Similarly, managers need to encourage their teams to apply such decision-making protocol without fear of retribution.

Products Developed Under This Project

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